Source scaling of Earthquakes in the Northeastern United States: Collaborative Research with Columbia University and Boston University

External Grant Award Number: 04HQGR-0028

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NEHRP Element(s): II, **Keywords:** Source Characteristics, Regional Seismic Hazards

Investigations undertaken

This project focuses on obtaining reliable source parameters for small to moderate size earthquakes in the Northeastern United States (NEUS), including the aftershocks of the Mw 5.0 Au Sable Forks, NY earthquake of 20 April 2002. Our research plan has three specific goals:

- *Determine accurate source parameters*. We use both individual spectral techniques, and empirical Green's functions to determine the source dimension, stress drop, and radiated energy of the $M \geq 2$ aftershocks using both local and regional data.
- *Validate previous regional wave studies in NEUS*. Kim and colleagues have determined source parameters for 49 earthquakes in NEUS using regional *Sg* and *Lg* waves (Figure 1). We plan to compare the results using local and regional waves for the Au Sable Forks aftershocks and use the local measurements to validate and calibrate the regional wave measurements. We will then have a catalogue of over 50 earthquakes with well known source parameters.
- *Investigate factors governing earthquake source process*. We intend to compare the Au Sable aftershocks, and other NEUS earthquakes, to earthquakes in a similar magnitude range in other tectonic settings to determine whether there are systematic differences in parameters such as stress drop or radiated energy. We will also compare them to larger magnitude earthquakes in stable continental regions.

Earthquake Source Scaling and the Physics of the Earthquake Rupture Process: Although small earthquakes are not themselves a serious hazard, they provide essential information about the earthquake rupture process on all scales. For example: How do earthquake ruptures start and grow? How do they interact with one another? What is the energy budget and stress level? Studies of small earthquakes form a vital link between even smaller scale laboratory studies and large damaging earthquakes. Abercrombie and Leary (1993) and Abercrombie (1995)

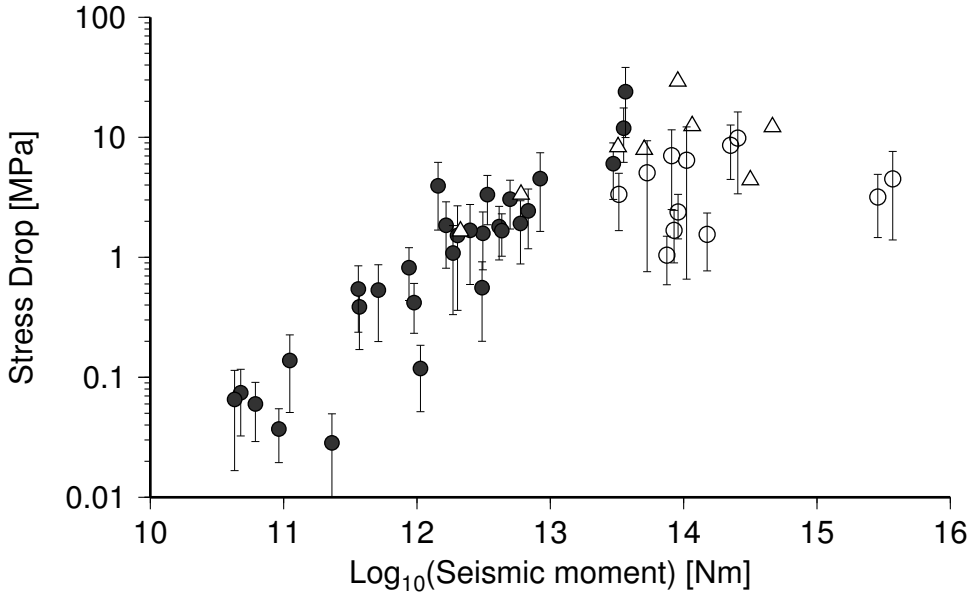

Figure 1: Corner frequencies of regional earthquakes in NEUS are plotted against seismic moment (Shi et al., 1998). Each corner frequency is plotted with an error bar which indicates the error of the mean values for the event across the network. *Filled circles* indicate the events for which only LCSN data were available. *Open circles* are for the events for which broadband USNSN and ECTN data were also used. The *triangles* are for the eight events with corner frequencies estimated from the empirical Green's function method (She et al., 1996).

compiled measurements of earthquake source parameters, mainly from active tectonic regions and found that the static stress drop was not magnitude dependent, at least above -1M (Figure 2). It is unclear whether these are directly relevant to NEUS. Comparison of earthquakes in different tectonic settings provides an opportunity to investigate the factors governing the earthquake slip, and hence learn about the physics of the earthquake rupture process. For example, studies of a small number of larger earthquakes in the NEUS predict a larger average stress drop (and higher shaking) than in the western USA. Shi et al. (1998) also find an apparent breakdown in constant stress drop below about 2×10^{13} Nm (Figure 1). At present it is unclear whether this is a real effect or a result of the different data and methods used.

Results

To date, we have collected and processed waveform data from aftershocks of the Mw 5.0 Au Sable Forks, NY earthquake, which is the most recent damaging earthquake to occur in the NEUS. There are 14 aftershocks with $M \geq 2$, that are well recorded by broadband and short-period seismic stations at regional ranges. About half of these aftershocks are also recorded by the portable seismic network stations at local ranges ($\Delta \leq 10km$). Preliminary analysis indicates that the largest aftershock (M_L 3.7) had a significantly different focal mechanism to the mainshock.

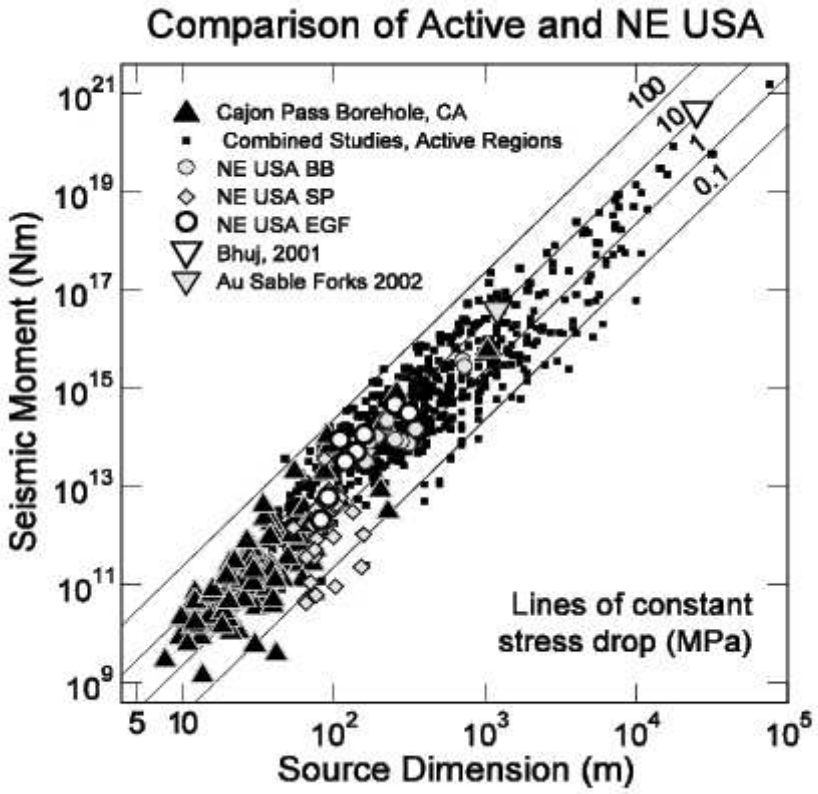

Figure 2: Source scaling relationships determined for California and other active tectonic regions (Abercrombie, 1995), compared to results from stable continental regions. The Northeastern U.S. results are from Shi et al. (1998). Note the apparent breakdown in scaling below 2×10^{13} Nm. Also plotted are preliminary results for the Au Sable Forks earthquake (Atkinson & Sonley, 2003), and the Bhuj, India, 2001 earthquake (Johnston, 2003). Note that they are above the average values for earthquakes in this size range in California.

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Non-Technical Summary

Earthquakes in the Northeastern United States (NEUS) are rare but have the potential to cause catastrophic damage and numerous casualties. Few earthquakes have been well recorded in the NEUS to provide useful ground motions for the research community. As a result, earthquakes and seismic wave propagation in the region are poorly understood. The aftershocks of the magnitude 5, 2002 Au Sable Forks, New York earthquake are by far the best recorded earthquakes to occur in the NEUS to date. The aim of the proposed work is to characterize the source processes of at least 50 small earthquakes in the NEUS, including the aftershocks of the 2002 Au Sable Forks earthquake. Reliable source characteristics are essential inputs for mapping the seismic hazard in the region.